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Stock Structure of American Shad, *Alosa sapidissima*, in the Gulf of Maine and Bay of Fundy

by

Michael J. Dadswell

Fisheries and Environmental Sciences
Department of Fisheries and Oceans
Biological Station
St. Andrews, New Brunswick E0G 2X0

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ABSTRACT

In the past, American shad have been managed on a river basin or ocean region basis. Both river and ocean fisheries exist in the Gulf of Maine-Bay of Fundy and have been exploited for the last 200 yr. Fisheries are located in the Saint John, Shubenacadie and Annapolis Rivers, and in Minas and Cumberland Basins and Shepody Bay in the upper Bay of Fundy. Landings in all fisheries have declined to historical lows, first because of reduced shad abundance, and finally because of low demand.

American shad are anadromous and exhibit homing to natal streams. Tagging, meristic and morphometric, otolith recognition and parasite studies all indicate shad aggregations in the Gulf of Maine region are a heterogeneous mixture of populations from all Atlantic coast rivers. There are two aggregations. A "summer" group, consisting of 60-80% USA river shad, migrates completely around the Gulf of Maine-Bay of Fundy between May and November. A "winter" group, consisting of largely Canadian and northern river USA shad, which remains in the western Gulf of Maine and on the Scotian Shelf during winter.

Spatial and chronological separation between both aggregations and their fisheries in the USA and Canada would permit the ICJ line to be used for statistical and management unit separation. However, for biological reasons, shad would best be managed by river basin or as one single east coast unit stock.

RESUME

Par le passé la gestion de l'alose savoureuse a été effectuée sur la base de bassins hydrographiques ou de régions océaniques. Il existe des pêches en cours d'eau et en mer de cette espèce dans la région du golfe du Maine et de la baie de Fundy où elle est exploitée depuis 200 ans. La pêche s'effectue dans les rivières Saint-Jean, Shubenacadie et Annapolis, dans les bassins des Minas et Cumberland, dans la baie Shepody et dans la partie intérieure de la baie de Fundy. Les débarquements de toutes les pêches sont tombés à des minima historiques premièrement en raison d'une diminution de l'abondance de l'alose et deuxièmement en raison de la faiblesse de la demande.

L'alose savoureuse est anadrome et revient à son cours d'eau natal. Les étiquettages méristiques et morphométriques, la reconnaissance des otolithes et les études des parasites indiquent tous que les agrégations d'aloses dans la région du golfe du Maine constituent des mélanges hétérogènes de populations provenant de tous les cours d'eau de l'Atlantique. Il y a deux agrégations, un groupe "d'été" composé de 60 à 80% d'aloses de cours d'eau américains qui migrent complètement autour de la région golfe du Maine-baie de Fundy entre mai et novembre, et un groupe "d'hiver" composé en grande partie d'aloses de cours d'eau canadiens et du nord des Etats-Unis qui restent dans la partie ouest du golfe du Maine et sur le plateau Scotian pendant l'hiver.

La séparation dans le temps et dans l'espace des deux agrégations et de leur pêche aux Etats-Unis et au Canada permettrait d'utiliser la ligne de démarcation de la CIJ pour la séparation statistique et administrative de l'unité. Toutefois, pour des raisons biologiques, il conviendrait mieux d'effectuer la gestion par bassin hydrographique ou d'après une seule unité de stock pour la côte est.

A. HISTORY OF MANAGEMENT AREA

The American shad, Alosa sapidissima (Wilson, 1811) is a large, anadromous clupeid. Shad spawn during spring in rivers from Florida to Quebec and, after juveniles spend the first summer in fresh water, they migrate to sea where they live 4-5 yr, reaching maturity at a mean size of 40 cm FL and 1 kg (Walburg and Nichols 1967). Shad are highly migratory, moving south to north and back again annually, following an ocean isotherm envelope of 7-17°C (McDonald 1884; Leggett and Whitney 1972) and homing to their natal rivers for reproduction (Hollis 1948; Melvin et al. 1986).

Because shad are anadromous, management regimes are normally established by river basin or on a state-province basis. In the Gulf of Maine region, management regimes are established for three rivers (Saint John, Shubenacadie, Annapolis) and four ocean regions (Minas Basin, Cumberland Basin, Shepody Bay, Saint John Harbour) (Table 1). Shad restoration programs are in progress on two other large Gulf of Maine rivers (Merrimack, Kennebec) and the re-established populations will be managed on a river basis in the future. Elsewhere in the ocean, there is no management (Table 1).

Present management units were first established by either the province or state in which a shad fishery existed. Most were established prior to 1850 (Perley 1852; Prince 1912). When the federal government assumed responsibility for fisheries in the Maritimes, the Dominion Commission of Fisheries undertook responsibility for management. The Department of Fisheries and Oceans (DFO) inherited this responsibility.

Management regions were also delimited on the basis of the local characteristics of the fishery, particularly timing of the ocean or river run at a locality. Management schemes were additionally designed to reduce by-catch of Atlantic salmon and limit shad catch for increased escapement (time restriction, etc.) (Table 1). No Gulf of Maine or Bay of Fundy shad fisheries are limited by a Total Allowable Catch (TAC).

There have been few recent modifications of shad management schemes. Management regions remained unchanged when the federal government took responsibility for fisheries management in the Maritimes. During the 1920's, a period of low shad abundance, the ocean fishery in the upper Bay of Fundy was closed for 2 yr in hope of rebuilding the stock (Jeffers 1932). This strategy proved unsuccessful for reasons which will be discussed later. The Saint John Harbour fall fishery for ocean shad was closed during the late 1960's because Saint John River landings had exhibited a decline. Since the 1970's, a number of shad fisheries in Canada have either been closed or had season length restricted to reduce by-catch of Atlantic salmon.

Management of American shad in the Gulf of Maine region is the responsibility of the Freshwater and Anadromous Division, DFO, Scotia-Fundy, the U.S. Fish and Wildlife Service and the State of Maine.

B. BIOLOGICAL BASIS FOR STOCK DEFINITION

History of Spatial Characteristics of Fishery

American shad is anadromous and, like many similar species, their populations exhibit a strong fidelity to a natal stream (Hollis 1948; Fredin 1954; Talbot and Sykes 1958; Carscadden and Leggett 1975; Melvin et al. 1986). Since stocks are bound to a particular stream, their abundance levels tend to fluctuate independently of each other (Fredin 1954; Talbot 1954; Walburg and Nichols 1967). Populations are influenced directly by pollution or habitat degradation events (damming) in their home streams (Stevenson 1898; Walburg and Nichols 1967; Chittenden 1974). In addition, recent work suggests most of the critical period when recruitment relationships develop occurs in the stream during the first summer of life (Crecco and Savoy 1984). For all of the above reasons, management of shad by river basin has been the accepted practice and should remain so in future since the reproductive and nursery areas are critical for stock survival. The dramatic decline of American shad catches on the Atlantic coast during the 1900's (Fig. 1), after systematic destruction of riverine habitat (Stevenson 1898; Walburg and Nichols 1967; Chittenden 1974; Jessop 1975), was ample demonstration of the need for riverine habitat to the wellbeing of the fishery. With restoration efforts concentrating on improving river habitat, many American shad stocks have shown a resurgence in abundance since 1960 (Miller et al. 1982; Crecco and Savoy 1984). Increased abundance is apparent from the shad catches in the upper Bay of Fundy. Catch per unit effort (CPUE) has increased by six times since 1970 (Dadswell et al. 1984a).

Historically, the large American shad catches in both commercial and sport fisheries have been along the Atlantic coast between Virginia and New York and in the major spawning rivers of that region (Delaware, Hudson, Connecticut) (Walburg and Nichols 1967). Landings peaked during the 1890's at 23,000 MT/yr but declined steadily to present levels of about 1000 MT/yr (Fig. 1). Decline of the fisheries is thought to be due largely to habitat destruction and, now that restoration efforts are progressing, abundance has increased. A major share of the shad catch in this region is now caught by sports fishermen (Leggett 1976; Miller et al. 1982). Shad fisheries in USA Gulf of Maine rivers were formerly in the range of 100-500 MT/yr each (Bigelow and Schroeder 1953), but are now extinct. Restoration programs are underway.

A limited ocean catch of shad is taken by groundfish gillnetters in the Jeffreys Ledge region. Catches peak in late fall-winter (Table 2). A directed purse-seine fishery for shad occurred off Mount Desert Island until after WWII (Talbot and Sykes 1958). Landings reached 500 MT in some years.

Recently, significant by-catches of shad have been made in deepwater (50-100 m), groundfish gillnet fisheries off Grand Manan (1000-3000 kg/d) (Dadswell, pers. obs.). This appears to be because of increasing shad abundance. Development of this fishery is hindered by lack of markets.

The shad fishery of the upper Bay of Fundy has existed since the earliest arrival of Europeans in the region. Perley (1852) identified the start of a weir fishery on the tide flats of Minas Basin, Cumberland Basin

and Shepody Bay by 1750. Prince (1912), writing for the Dominion Shad Commission (1908-1910), described the abundance of shad in this region during the 1800's and the relative ease with which primitive and/or simple capture methods (stake seines, brush weirs) could capture thousands of shad on a single tide. The shad fishery was important to the economy of the Bay of Fundy and a Special Act of the Nova Scotia Legislature was passed in 1840 for its regulation, one of the first in Canada (Perley 1852; Dadswell et al. 1984b). After 1840, driftnets became the major means of capturing shad and at the same time a large export trade in salt shad began with the eastern United States (Perley 1852). In the 1870's, collection of fisheries statistics commenced and the course of the fishery could be followed.

Between 1870 and 1900, annual shad landings for the upper Bay of Fundy were 1.0-2.0 x 10^5 kg/yr (Fig. 2) and constituted two-thirds of total Canadian shad landings. After 1900, landings declined drastically as a result of markedly decreased shad abundance (Prince 1912) and have remained at low levels (10-20 MT) up to the present, although abundance now appears to be somewhat restored (Dadswell et al. 1984a) and landings reflect low effort (Fisheries and Oceans Canada, Fisheries Statistics). The course and decline of landings were very similar to those of the eastern United States during the same period (Fig. 1).

Unlike other shad fisheries, which are concentrated on spawning rivers or their estuaries and exploit adult, spawning shad during a short spring season (Leim 1924; Walburg and Nichols 1967), the upper Bay of Fundy fishery occurs in shallow, oceanic water and non-spawning shad are captured during an extended summer-fall season of 5 mo (Fig. 3) (Perley 1852; Leim 1924; Dadswell et al. 1984a). Along the rest of the Atlantic coast, shad are available to fishermen in shallow water only during the spawning season and are not captured afterward unless nets are fished offshore in water of 50-200 m (Talbot and Sykes 1958; Gabriel et al. 1976; Neves and Depres 1979). The presence of a large fishery to shallow oceanic water for non-spawning shad suggests the turbidity in the upper Bay of Fundy, absent during summer and fall in other coastal regions, creates an abundance of shad by bringing them into the surface zone (Dadswell et al. 1983).

A small ocean fishery for shad used to exist in Saint John Harbour during the fall (Gabriel et al. 1976) but was closed in the late 1960's because of declining catches during the spring river run (Fig. 4). However, results from tagging shad in the Harbour during fall indicate this group of fish is part of the general oceanic "summer" run in the Bay of Fundy (Fig. 5). These shad apparently penetrate the harbour in large numbers as they pass by on their way out of the Bay of Fundy. Efforts are in progress to re-open this fishery.

Other major shad fisheries in the Gulf of Maine-Bay of Fundy region are in the Saint John, Shubenacadie and Annapolis Rivers. These are spring fisheries directed towards spawning adults. The largest fishery is the Saint John River where landings exhibit extreme variability but were 200-450 MT in some years (Fig. 4). Shad landings in the Shubenacadie are traditionally smaller, ranging between 10-60 MT/yr (Morantz 1978). Commercial landings in the Annapolis River are low (5 MT/yr) because of the restrictive nature of fisheries regulations (Table 1). On the other hand, the sports fishery in this river is well developed and the population large (Melvin et al. 1985).

Definition of Stock Structure

Tagging and population discrimination studies have shown shad in the ocean migrate together in aggregations consisting of numerous stocks (Talbot and Sykes 1958; Dadswell et al. 1983, 1984a; Melvin 1984). Early findings suggested there was one Atlantic aggregation that migrated between Virginia and the Gulf of Maine on a seasonal basis following ocean-surface isotherms of 13-18°C (Talbot and Sykes 1958; Leggett and Whitney 1972). Neves and Depres (1979) analyzed trawl catches of shad from annual assessment cruises (NMFS) and hypothesized there was more than one ocean group each with separate wintering sites.

Between 1979 and 1984, in response to possible tidal power development, an intensive study was conducted on shad biology and stock structure in the Bay of Fundy (Dadswell 1984a). Work involved tag-recapture studies (Dadswell et al. 1983, 1984a), as well as population discrimination methods using meristics and morphometrics (Melvin 1984), otolith recognition techniques (Williams 1985) and parasites (Dadswell et al. 1984b).

A total of 13,400 shad were tagged and released in Cumberland and Minas Basins and the Saint John Harbour (Table 3). Tag returns (650) were 7% from Canadian marine locations, 28% from coastal USA, 7% from Canadian rivers, and 58% from USA rivers (Fig. 6). These data indicate that between 60 and 80% of the shad occurring in the Bay of Fundy during the summer were of USA origin. When tag returns were analyzed for seasonal distribution, the north to south and return migration pattern was evident (Fig. 7). Of particular interest, however, was the distribution of shad at sea during winter and during summer in years subsequent to tagging in the Bay of Fundy. These returns indicated that after spending the summer in the Bay of Fundy a shad may winter in one of three sites, off Florida, off North Carolina-Virginia, or in the Gulf of Maine-Nova Scotia Shelf region. In the subsequent summer, the shad might return to the Bay of Fundy, migrate to the Gulf of St. Lawrence or to Newfoundland-Labrador (Fig. 8). The Gulf of Maine-Bay of Fundy aggregation in any given year, therefore, consist of shad from all stocks on the Atlantic coast and from each overwintering site but stock proportions differ seasonally.

Population discrimination studies have defined this stock structure further. Melvin (1984) collected shad from 13 rivers spanning the reproductive range of the species (Fig. 9) and examined 10 meristic and 16 morphometric characters to develop linear discrimination functions (LDF) for each river population. Multivariant statistical procedures (Hotelling T^2) were employed to remove variables which differed significantly ($P < 0.05$) between sexes, year of sampling and spawning-run collection period. The highest mean percent proper classification was achieved by the allocation of shad into regional groups as follows: Cape Lookout south, Cape Cod to Cape Lookout, Gulf of Maine-Bay of Fundy, Gulf of St. Lawrence (Fig. 9). For pooled meristic and morphometric variables correct classification was 87.2% for males and 82.4% for females. These discriminant functions were then used to assign origin-unknown Cumberland Basin shad samples collected in 1979-81 to regions. Regional comparisons of seasonal trends of LDF classification and tag-return findings were similar (Fig. 10). Southern shad (regions 1 and 2) were less abundant during the early part of the run (June) at low water temperature (<14°C) but reached peak abundance during

the middle of the run at highest water temperature (18°C) (Fig. 3; Dadswell et al. 1983). Northern shad (regions 3 and 4) were generally most abundant at lower water temperatures, early and late in the run.

Using differences in ring zonation of otoliths collected from the same shad used by Melvin, Williams (1985) was able to divide Atlantic coast river shad populations into three groups, Canadian (regions 3 and 4), middle USA (region 2), and southern USA (region 1). Appearance criteria correctly distinguished group identity 93% of the time. When these criteria were applied to shad collected in the upper Bay of Fundy, the pattern of northern shad early and southern shad later in the Minas Basin run again emerged (Fig. 11).

Results from analysis of visceral parasites of shad from Cumberland Basin were not as conclusive, perhaps because parasites were only collected one year (1979). When compared to the parasitic faunas of shad captured within spawning rivers, however, relative abundance of parasites from shad taken early in the run were grossly similar to northern rivers and those captured in mid- to late-run were most similar to southern rivers (Fig. 12; Dadswell et al. 1984b).

Further analysis for stock structure of shad in the Gulf of Maine-Bay of Fundy requires examination of tag-return information. When tag returns are grouped chronologically by Julian-day, it becomes evident the run period is different in each part of the Bay of Fundy (Fig. 13). Shad enter the Bay during April-May on the southern (Nova Scotia) side. The run reaches the head of the Bay in early June and peak abundance occurs during early July (Fig. 3). In the upper Bay, two events apparently occur: 1) the run divides by chance on Advocate Head with a portion going to each of Minas and Cumberland Basins, and 2) shad which migrate first to Minas Basin also migrate through Cumberland Basin before progressing out of the Bay of Fundy on the northern side between August and October (Fig. 13). A coincidental tagging study of spawning shad in the Annapolis River indicates arrival of fish at the head of the Bay from this population has equal likelihood in either basin and is by chance (50:50) (Fig. 14). Shad arrive from Annapolis River at the same time in either basin during the early run but only occur in Cumberland during the late portion of the run. When shoreline length is accounted for, migration rates of all tagged shad are similar and average 3.7±0.94 km/d (Dadswell et al. 1984a).

Departure from the Bay of Fundy through the Gulf of Maine takes two routes. One contingent of shad follows the Maine coastline approximately along the 100 m line (Fig. 15) and passes Portland-Cape Ann in October and November (Table 2). The other contingent leaves via the eastern shore of Grand Manan, Brier Island and S.W. Nova Scotia (Fig. 15). The western contingent appears to migrate out of the Gulf south to Virginia and Florida. The eastern group, which appears to consist largely of Bay of Fundy or northern shad moves off on the Scotian Shelf and overwinters from Sable Island west to Cape Ann, Mass. (Fig. 16). The Scotian Shelf contingent is joined in winter by shad migrating south from the Gulf of St. Lawrence and Labrador (Fig. 17). In spring, portions of this contingent migrate back to the Bay of Fundy (Fig. 16), to the Gulf of St. Lawrence or Labrador (Fig. 16, Fig. 8), and possibly south to USA spawning streams (Fig. 17).

In conclusion, the American shad stock structure in the Gulf of Maine can be best described as two aggregations with intermixing. Each aggregation is made up of varying proportions of stocks from the entire Atlantic coast and separation has a large seasonal component. Shad present in summer are drawn largely from USA populations (60-80%) and those present in winter may be largely from Canadian or northern USA rivers. Since shad from Canadian rivers, both in the Bay of Fundy (Fig. 18) and the Gulf of St. Lawrence (Fig. 17), also migrate south to Virginia (Vladykov 1956; Melvin et al. 1986), intermixing of populations is complete.

C. STOCK BOUNDARIES FOR STATISTICS AND MANAGEMENT

Management

Managing the ocean fisheries of American shad would only be practical through use of river region TAC's with a large degree of cooperation between Canada and the USA. An adequate understanding of shad population level can only be determined from assessment of river populations since ocean distribution is spread over a wide area.

However, the two aggregations which occur in the Gulf of Maine are separated both chronologically and spatially and could be considered as two management and statistic units. Except for those shad which join the "winter" group, the entire "summer" group has left the Gulf of Maine when they arrive. A two-unit concept would also work when considering either aggregation individually since the majority of the "summer" group is either all in the Bay of Fundy during summer (Fig. 7) or all in the Gulf of Maine in fall, and the winter group is divided up between an aggregation on the Scotian Shelf and one in the western Gulf of Maine or southern Georges Bank slope. The ICJ line would provide the most logical unit division since division already exists biologically in this manner.

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Table 1. Summary of management regulations for Atlantic coast American shad (after Rulifson and Huish 1982).

Region	Gear	Season	TAC
Rivers - USA			
Florida-North Carolina	11.5 cm stretch gillnet	Jan. 1-Apr. 15, weekend closures	None
Virginia	12.7 cm minimum	weekend closures	None
Maryland	Closed due to low population levels		
Delaware-Massachusetts	12.7 cm minimum	weekend closures	None
Maine	All populations extinct, restoration in progress		None
Ocean - USA			
Entire coast	No restrictions	No closed season	None
Rivers - Canada			
Saint John	12.7 cm stretch	May 1-June 7, weekend closures	None
Shubenacadie	12.7 cm stretch	Apr. 1-May 15 weekend closures	None
Annapolis	Scoop-nets only	Mondays-Tuesdays May 1-31	None
Oceans - Canada			
Minas Basin	12.7 cm stretch	May 1-Aug. 10 Friday noon-Sunday noon closed	None
Cumberland Basin	12.7 stretch	May 1-Sept. 30 weekend closures	None
Shepody Bay	12.7 cm stretch	May 1-Aug. 15 weekend closures	None
Saint John Harbour	Closed, May Open 1986	Sept. 1-Oct. 30	

Table 2. American shad landings (kg) by month at ocean ports in Maine during 1975-79 (source: Maine Department of Fisheries).

Month	Portland	Kennebunkport	Total
June	727	657	1384
July	720	222	942
August	-	401	401
September	422	317	739
October	1239	2124	3363
November	4204	10551	14755
December	9133	6451	15584
January	1418	1104	2522
February	4757	40	4797
March	618	-	618
April	91	1290	1381
May	1476	675	2151

Table 3. Site and number of shad tagged in the Bay of Fundy 1979-1984.

Year	Cumberland Basin	Minas Basin	Saint John Harbour
1979	512		
1980	3156		
1981	2600		289
1982	600	1900	349
1983	100	2502	
1984	-	1400	-
	6968	5802	638

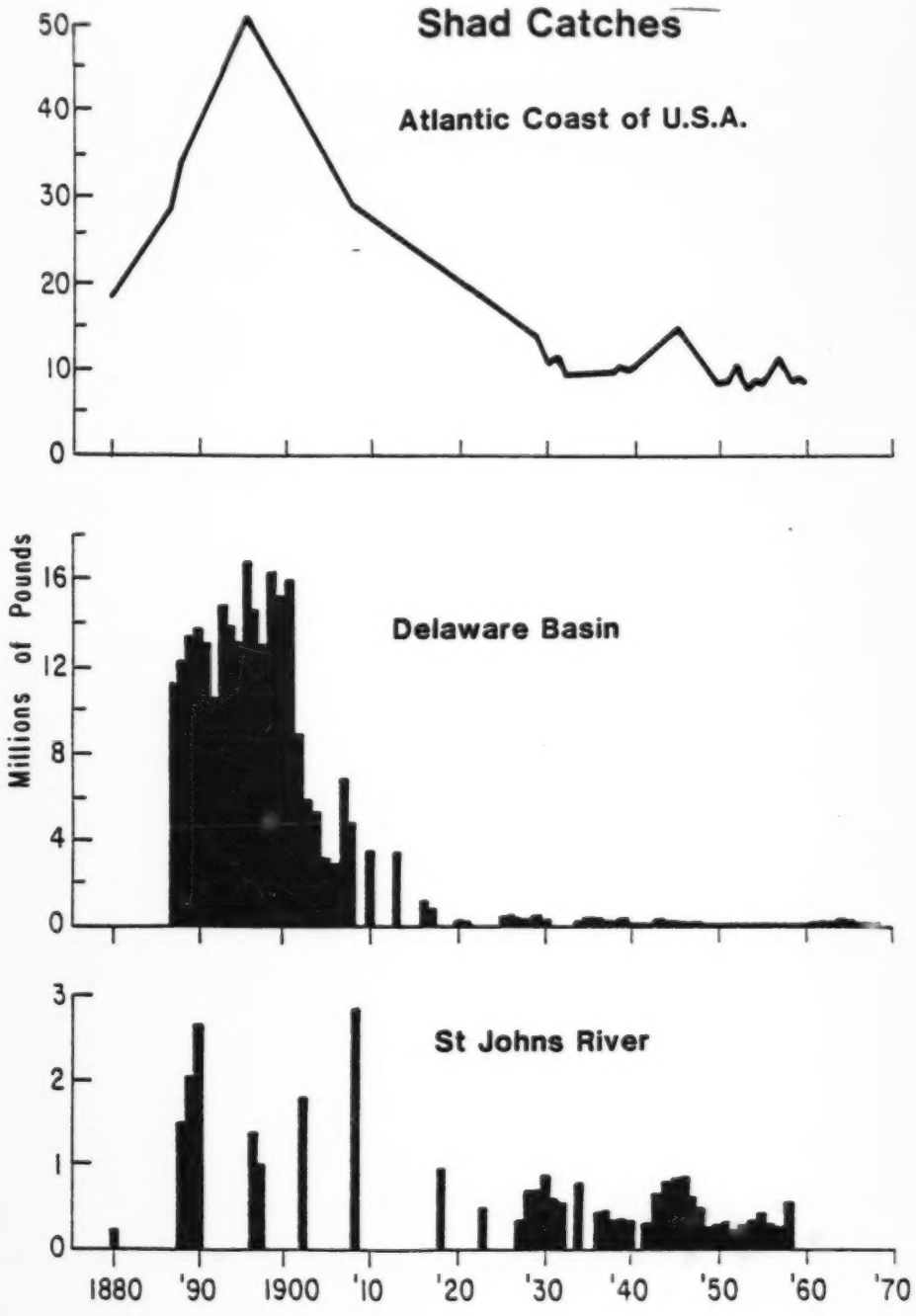

Fig. 1. Annual commercial landings for the eastern United States and various river systems during 1880-1970.

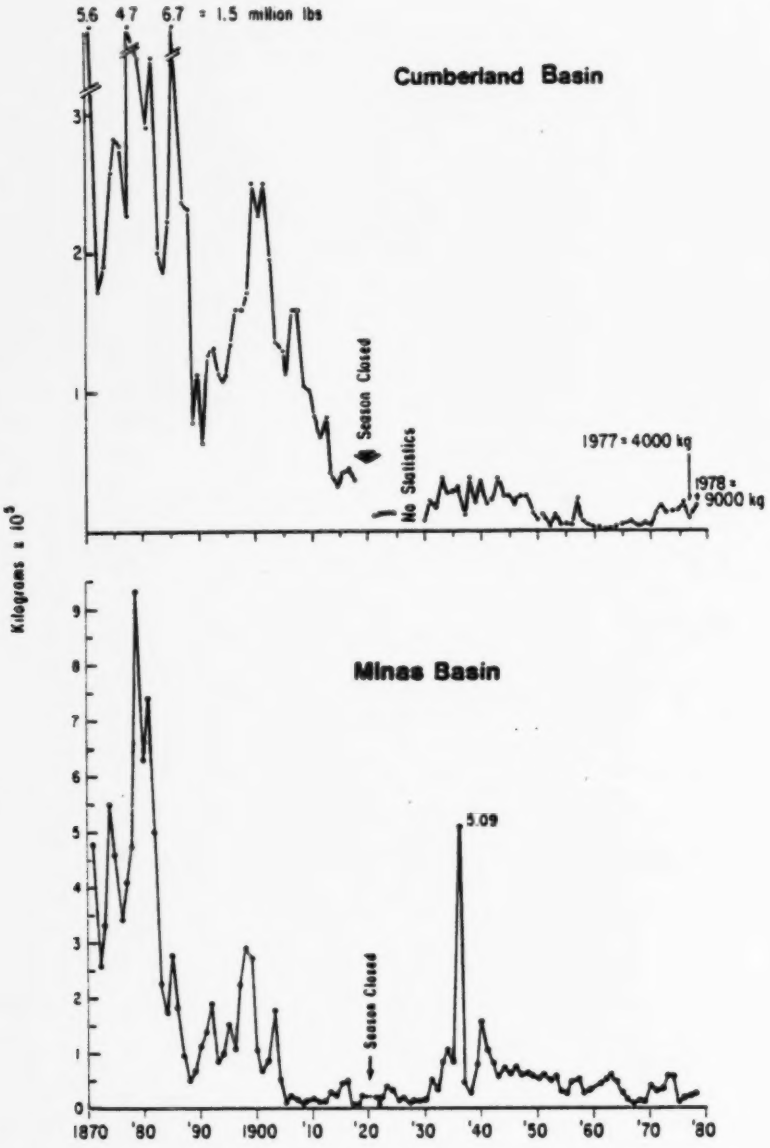

Fig. 2. Annual commercial landings for Cumberland and Minas Basin from 1870-1978.

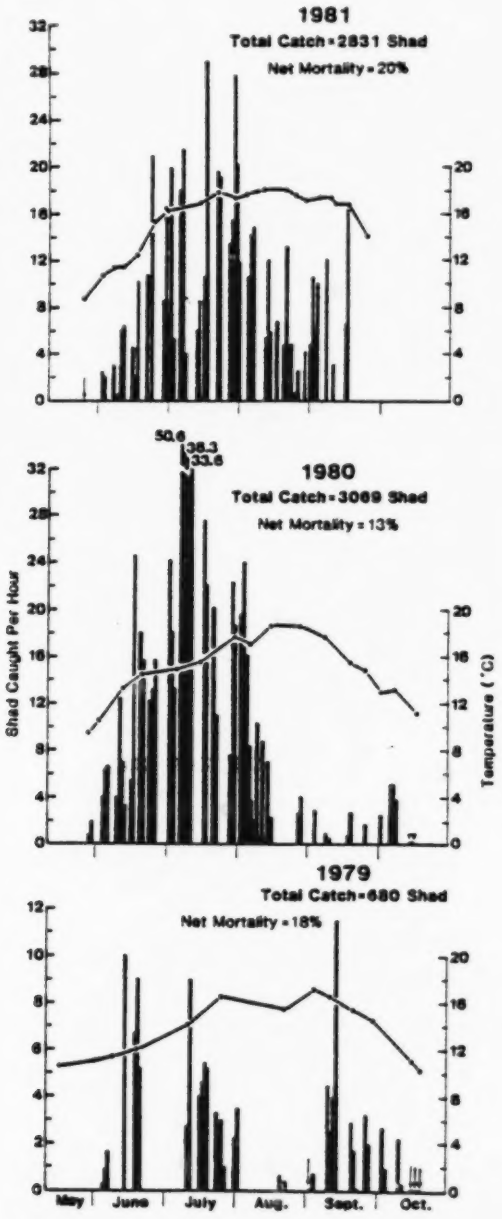

Fig. 3. Daily shad catch/hour with 500 m of 12.7 cm stretched-mesh multifilament nylon gillnet in Cumberland Basin, May-October, 1979-1981. Arrows indicate fishing days when few or no shad were captured.

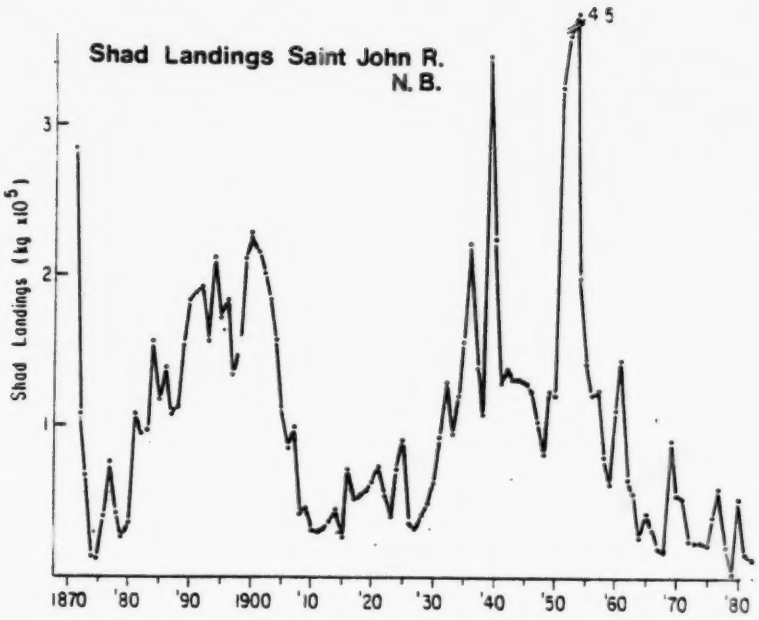

Fig. 4. Landings of American shad for the Saint John River and Harbour 1870-1982.

Fig. 5. Locality map for recaptures of American shad tagged in Saint John Harbour 1981-82. There were 39 returns from 638 applied tags for a return rate of 6.1%.

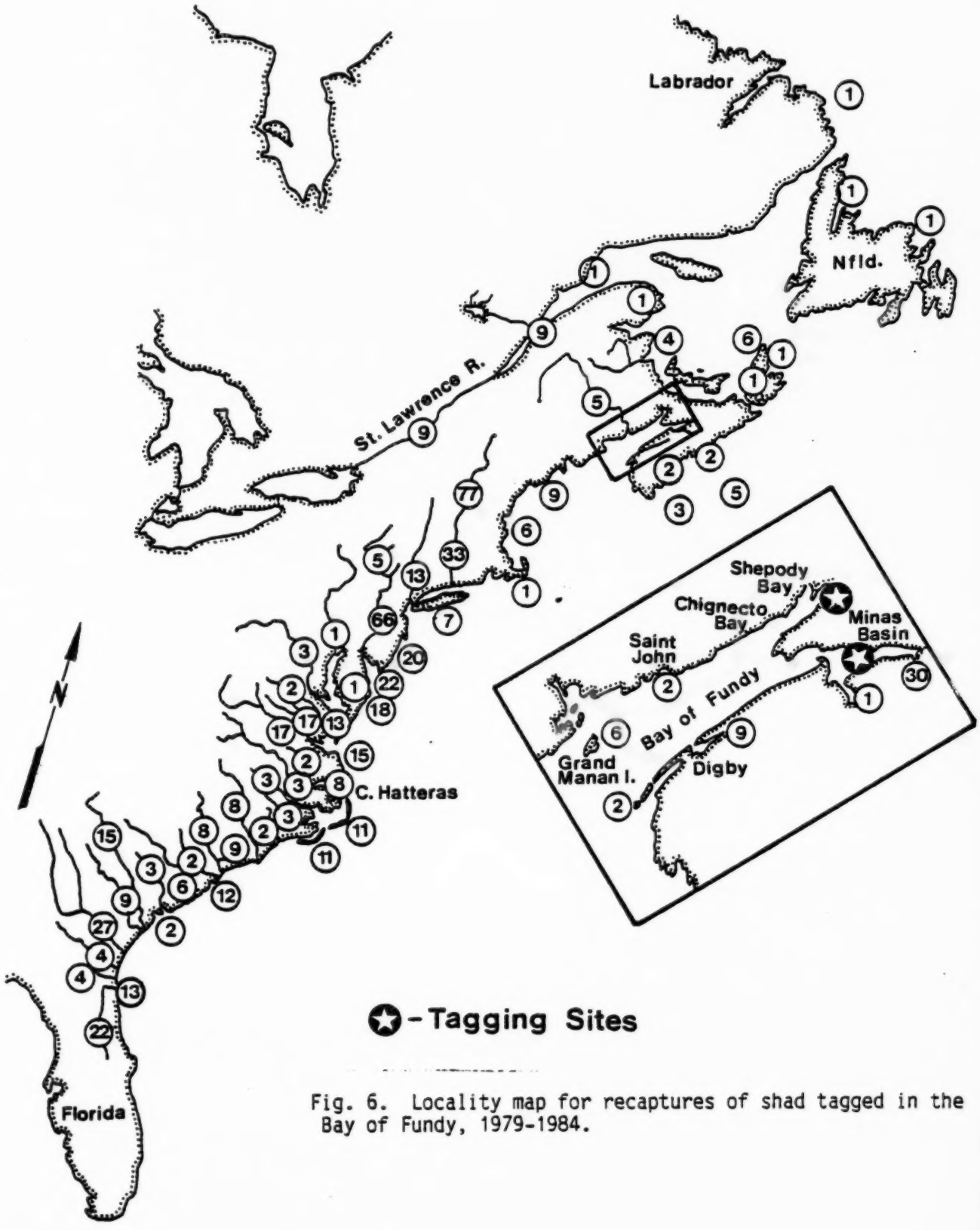

Fig. 6. Locality map for recaptures of shad tagged in the Bay of Fundy, 1979-1984.

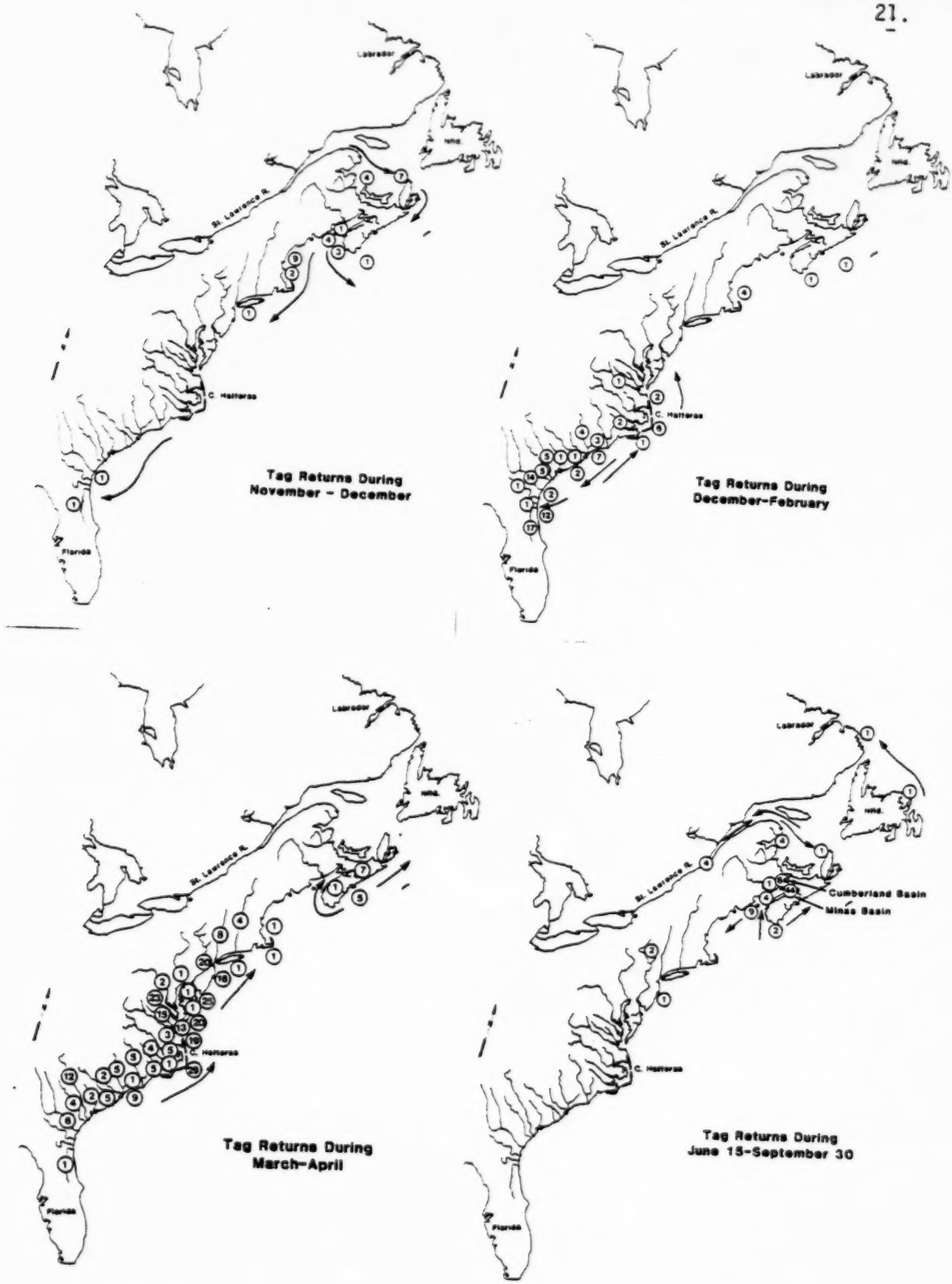

Fig. 7. Seasonal distribution of tag returns from American shad tagged in the Bay of Fundy.

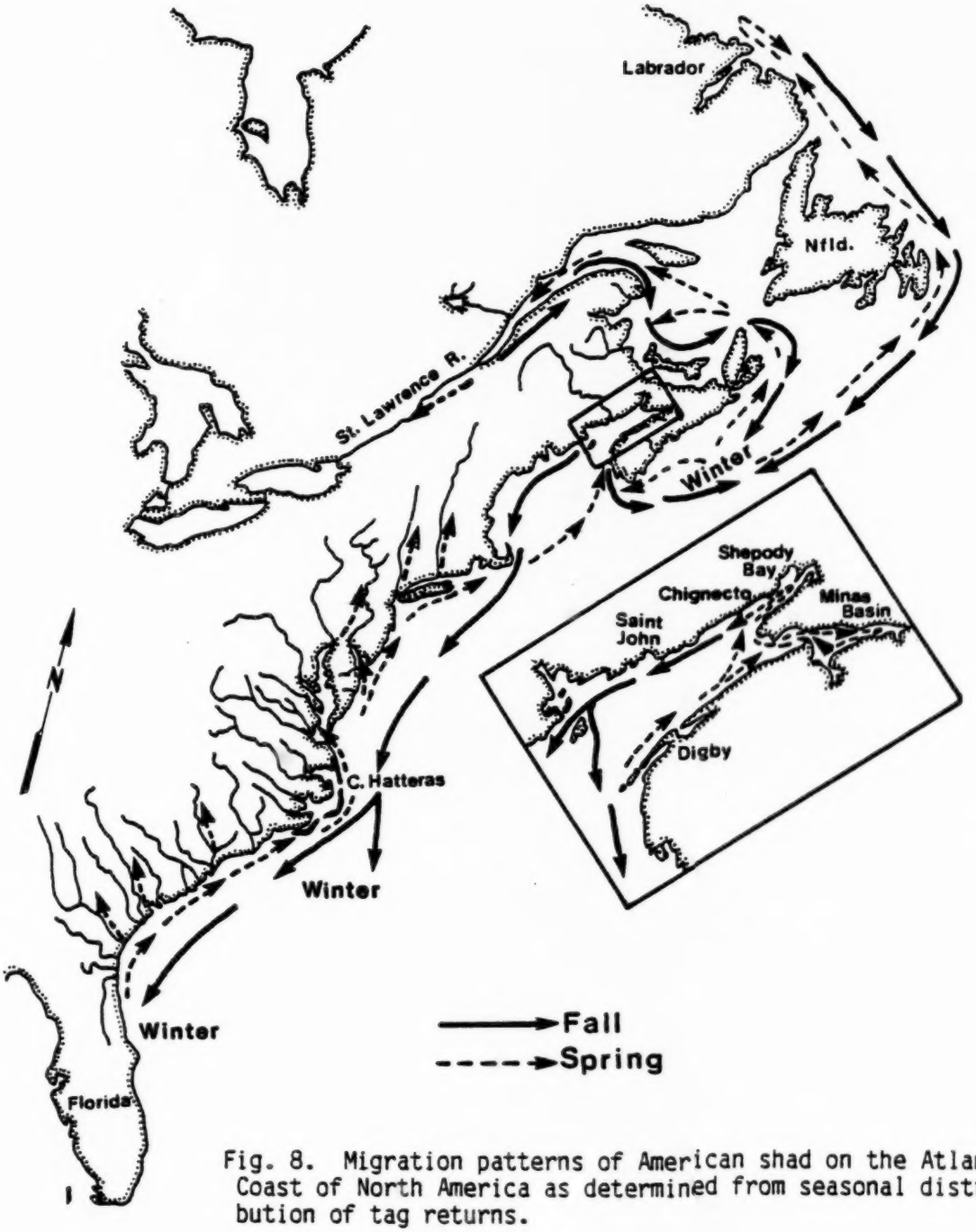

Fig. 8. Migration patterns of American shad on the Atlantic Coast of North America as determined from seasonal distribution of tag returns.

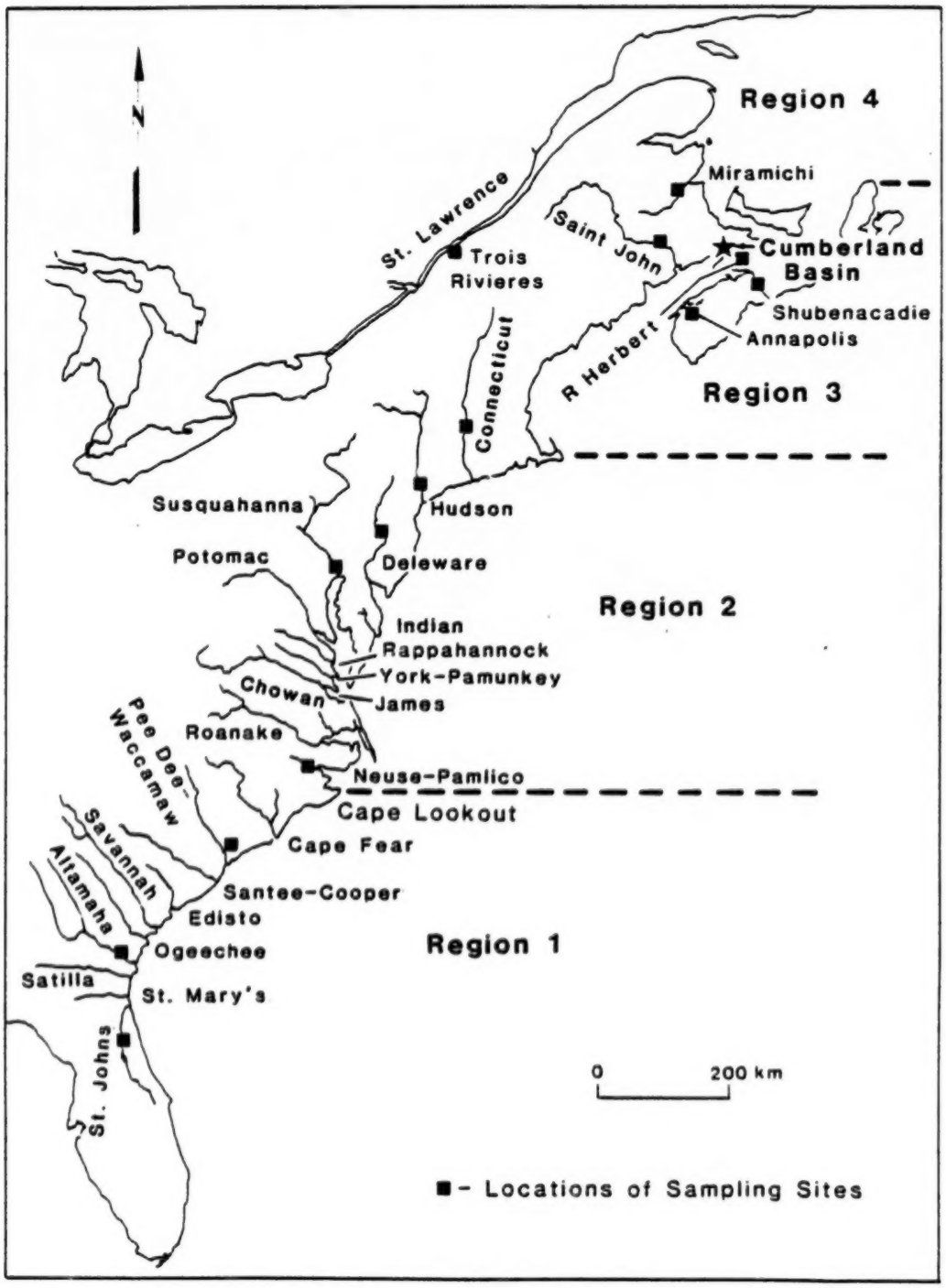

Fig. 9. River collecting sites for American shad populations on the Atlantic coast.

TAG RETURNS

10 13%	12 15%	37 49%	9 11%	4 5%	7 9%	Cape Hatteras South
12 13%	17 19%	38 54%	14 16%	4 4%	5 5%	Cape Cod South
3 19%	7 44%	2 13%	1 6%	1 6%	2 13%	Bay of Fundy
3 33%	2 22%	2 22%	2 22%	0	0	Gulf of St. Lawrence

POPULATION DISCRIMINATION

2%	3%	5%	6%	9%	17%	Cape Hatteras South
8%	20%	33%	34%	33%	31%	Cape Cod South
76%	61%	51%	38%	41%	46%	Bay of Fundy
14%	16%	11%	22%	17%	16%	Gulf of St. Lawrence
June	July 1-15	July 16-31	Aug. 1-15	Aug. 16-31	Sept.	

Fig. 10. Top: Number of tags (upper left corner) and percent of total returns from a geographic region for the weekly or monthly periods of tagging in Cumberland Basin.

Bottom: Percent of total sample by period from a geographic region as determined by LDF for shad collected in Cumberland Basin.

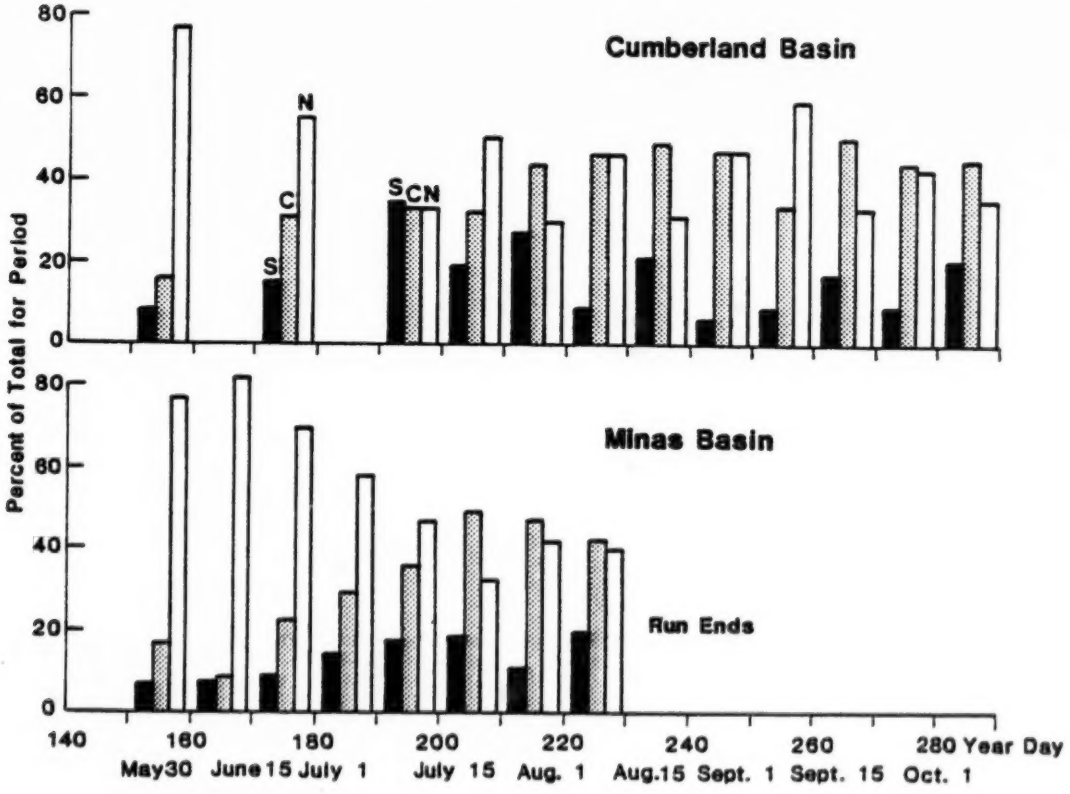

Fig. 11. Bi-weekly proportion of Canadian (N), middle USA (C), and southern USA (S) shad in samples from Minas Basin 1983-85 determined by otolith appearance criteria.

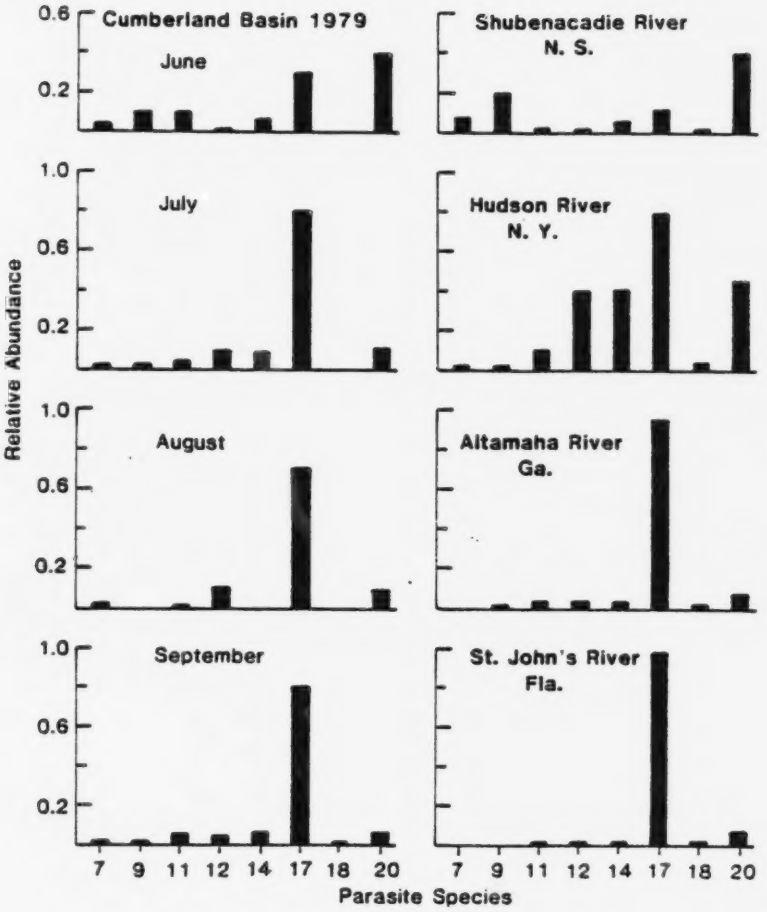

Fig. 12. Relative abundance of eight visceral parasites of shad from samples taken in June, July, August and September, 1979, in Cumberland Basin and from two northern and two southern rivers during the 1980 spawning runs. Parasites are: (7) Derogenes varicus, (9) Hemiurus levinseni, (11) Lecithaster spp., (12) Genitocotyle atlantica, (14) Diplostomulum spathecum, (17) Scolex pleuronectis, (18) large pleurocercoid, (20) Hysterothylacium aduncum.

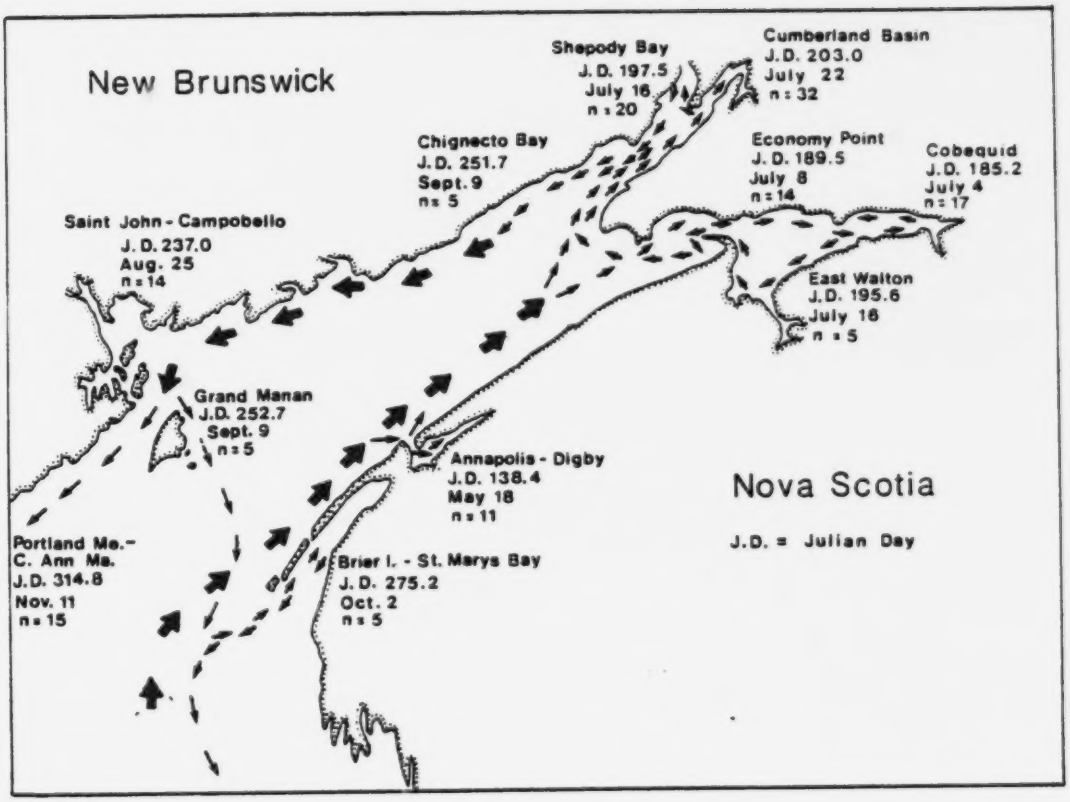

Fig. 13. Migratory route and mean days of recapture for tagged American shad in the Bay of Fundy.

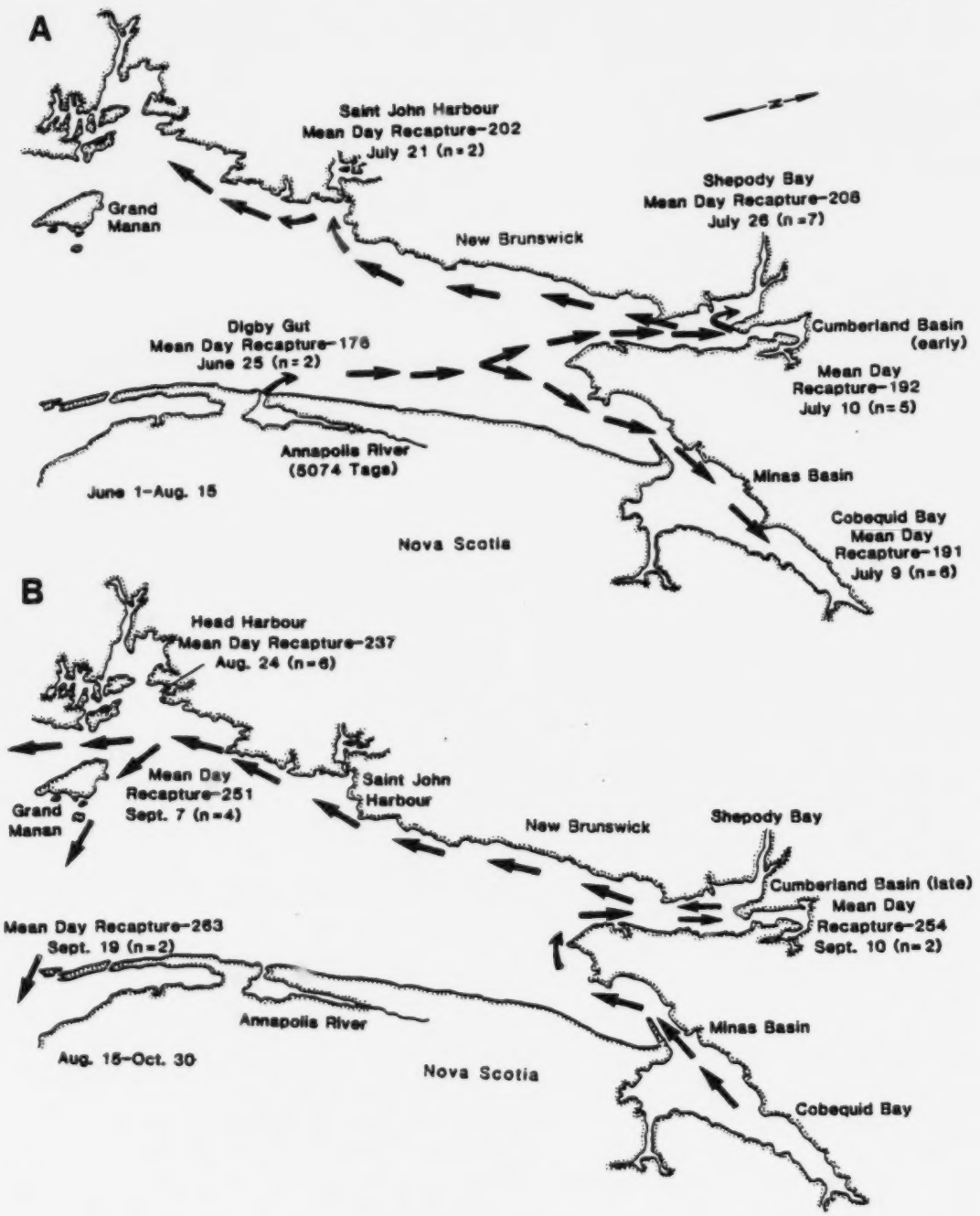

Fig. 14. Migration of the Annapolis River American shad population in the Bay of Fundy after its spring-spawning run. A) June 1-Aug. 15. Population migrates inward in Bay of Fundy, divides in two equal groups, moves to head of embayments. Cumberland contingent migrates out of inner end and down western shore first. B) Aug. 15-Oct. 30, Minas Basin contingent moves to Cumberland, then down west side of Bay past Grand Manan.

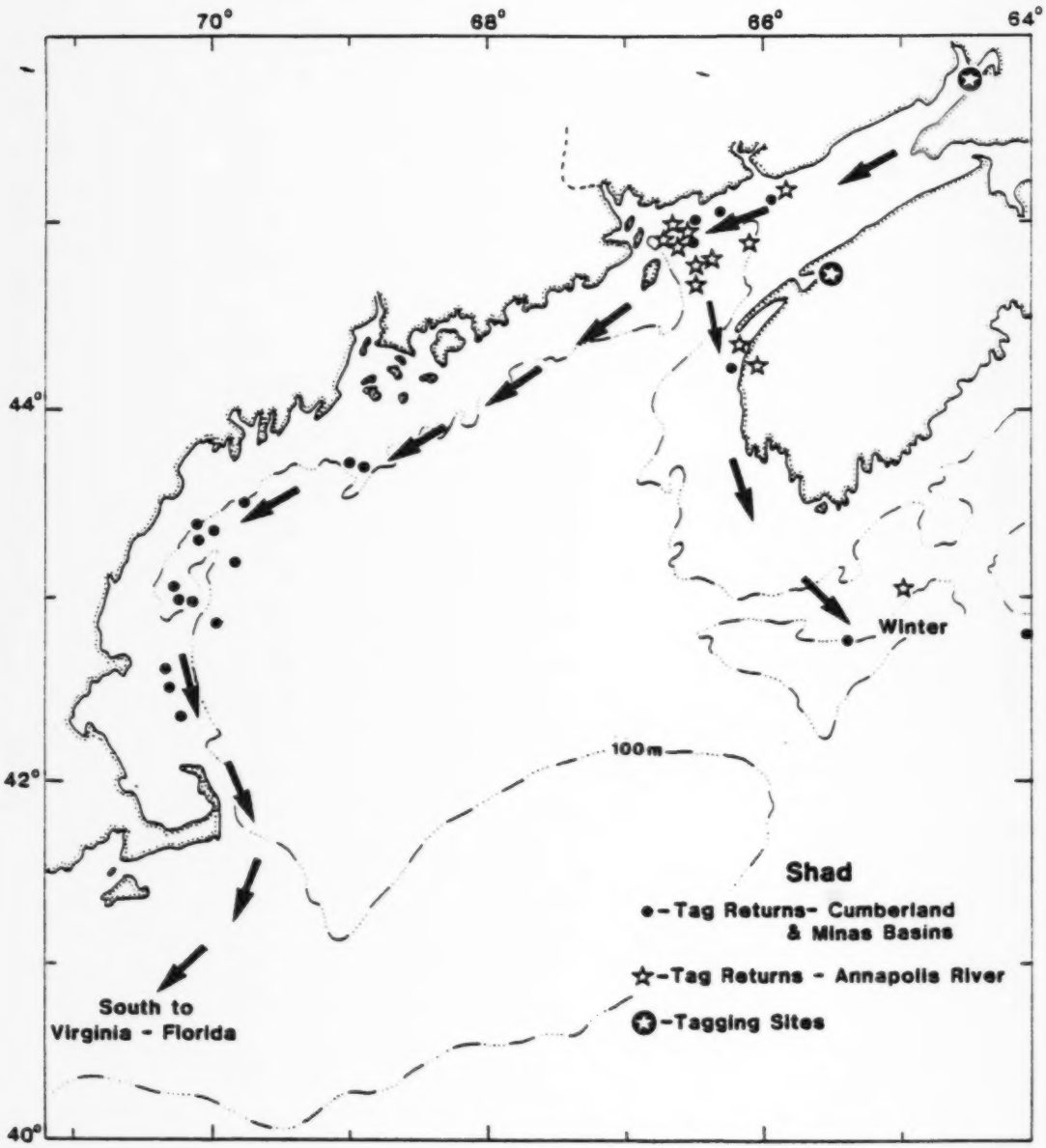

Fig. 15. Migration of American shad out of the Bay of Fundy in fall as indicated by tag returns. Many return localities were fixed accurately by fishermen using Loran.

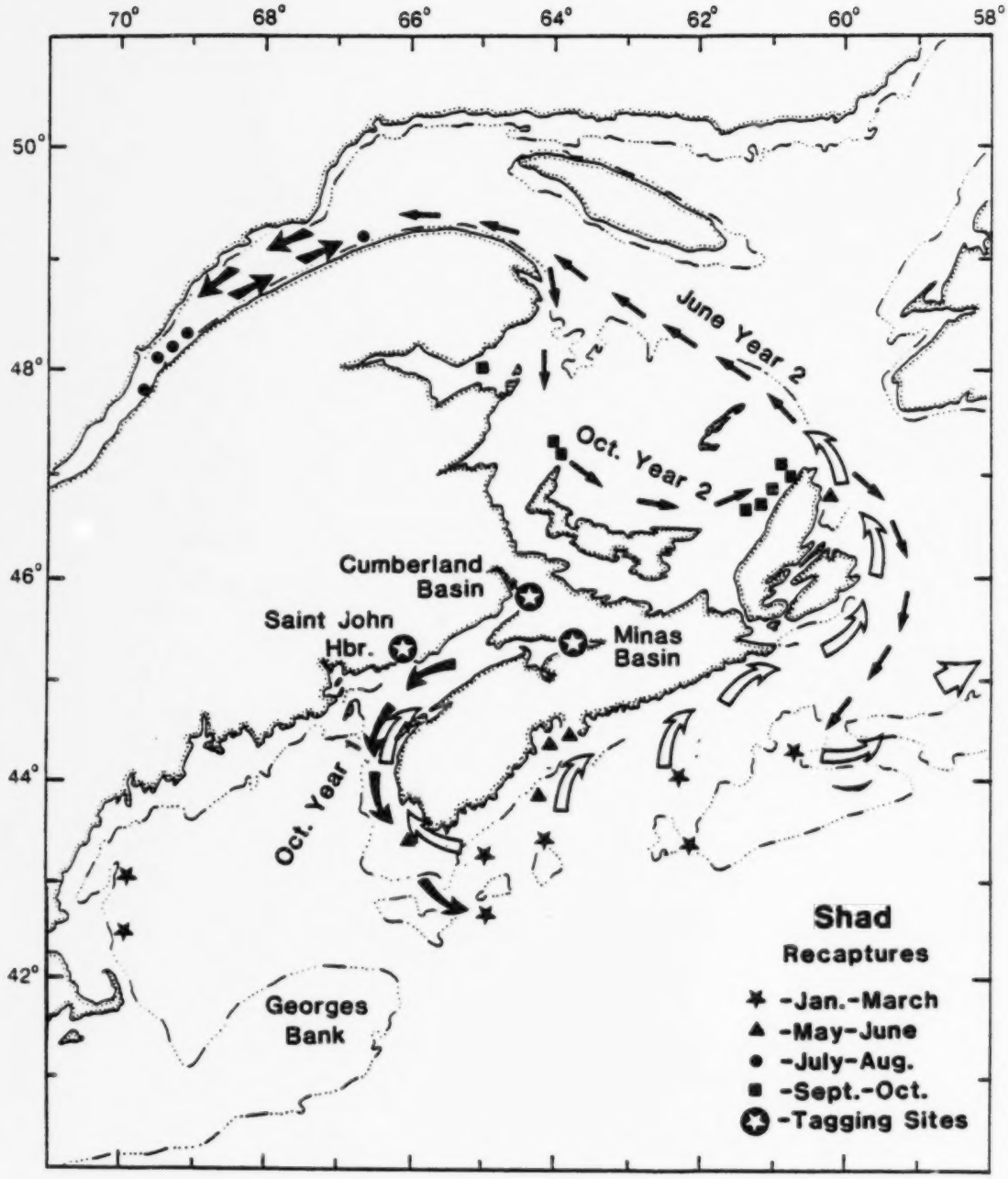

Fig. 16. Winter distribution of tagged American shad recaptured on the Scotian Shelf and subsequent (Year 2) migration patterns as determined from chronological sequence of tag returns.

Fig. 17. **Tag Returns from 1886 Tags Applied at Ile Verte, St. Lawrence River (Vladykov, 1956)**

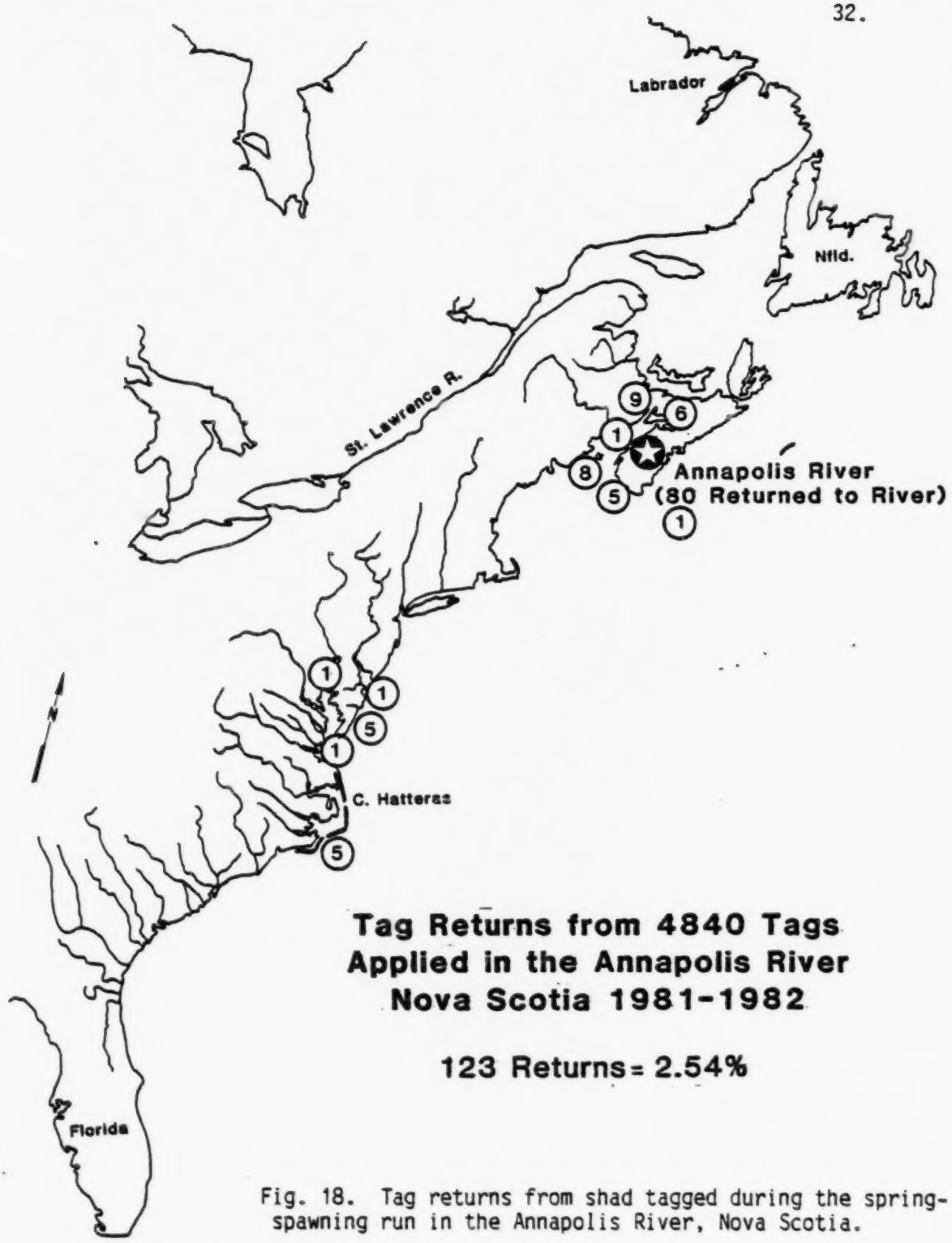

Fig. 18. Tag returns from shad tagged during the spring-spawning run in the Annapolis River, Nova Scotia.